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PETROGRAPHIC CLASSIFICATION OF THE IRONSTONE AND SLATE FORMATIONS IN OUTWASH DEPOSITS EAST OF KAKABEKA FALLS, NORTHWESTERN ONTARIO

by

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ABSTRACT

The petrographic analysis procedure LS-609 is subject to periodic review. Factors applying to the various rock types are changed to reflect current experience from laboratory studies and field performance. This case history is documented as an example of this review procedure.

Petrographic number determinations on Granular A material from the Deadman Pit east of Kakabeka Falls have indicated that it is marginal to unsuitable. A limited field performance study was undertaken on this material. It is concluded that the material has performed adequately in Highway 11/17 over a period of three years. The existing petrographic classification of Ironstone is considered too harsh, and is redefined. The introduction of granular correction factors to the Ironstone type is recommended.

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INTRODUCTION

The Soils and Aggregates Section, at the request of the Geotechnical Section, Northwestern Region, has investigated the petrographic classification of the ironstone, slate and shale materials in glacial deposits west of Thunder Bay. Unacceptable petrographic analysis results were obtained on material from a pit previously accepted for granular.

Granular materials from the Deadman Pit (Towland-Hewitson, Kakabeka #16, Paipoonge Township, Lot 35, Concession III) were investigated. The location of the Deadman Pit is shown in Figure 1. Previous test results indicated the deposit to be of marginal, but acceptable, quality for use as Granular A. The proposed extension of the Thunder Bay Expressway west to 5th Line (W.P. 906-78-01) consequently initiated the current investigation of these materials. This study included field visits, sampling of Granular A from Highway 11/17, and laboratory testing. The project has been discussed with Regional Geotechnical and Quality Assurance Sections.

GEOLOGY OF DEPOSIT

As shown on Figure 1, the area north of Kakabeka Falls is underlain by Archean Granite and metavolcanic rocks. The study area, i.e. south and east of Kakabeka Falls, is underlain by the metasedimentary Rove and Gunflint Formations of the Animikie Group. The contact between the Rove and Gunflint Formations, as shown on geological compilation map 2065 (see Figure 1), is poorly defined between Kakabeka Falls and Thunder Bay along the Kaministikwia River. This is due to the overlying Kaministikwia Delta and Outwash Deposits (see Figure 2), which blanket the bedrock to varying depths. The Rove Formation consists predominantly of shales and greywackes. The Gunflint Formation consists mainly of ferruginous chert rocks commonly known as Iron Formation. Interbedded with these rocks are some tuffs, shales and greywackes.

The Kaministikwia Delta and Outwash Deposits are thick glacio-deltaic deposits of gravel, sand and clay originating mainly from the north along the Kaministikwia River course, previously a meltwater channel (see Figure 3 showing gravel deposits in the Deadman Pit). Some of the glacial materials have been derived locally from the Gunflint and Rove Formations. The glacial materials are geologically highly varied. the average composition of four petrographic examinations on samples from the Deadman Pit is summarized from Table 1 as follows:

Rock Type	%
Granite-Diorite-Gabbro	47.3
Iron Formation	27.6
Greywacke-Argillite	6.6
Flint-Jasper	4.4
Gneiss-Schist	4.2
Sandstone-Arkose	3.3
Trap	1.7
Shale & Slate	1.3
Volcanic	1.3
Chert-rich rocks	1.1
Sibley	0.6
Quartzite	0.3
Ochre	0.1

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The Iron Formation originates from the Gunflint Formation and from isolated deposits in the Metavolcanics north of Kakabeka Falls (see Figure 1). Iron Formation makes up nearly 30 percent of the gravels. The manner in which they are classified, therefore, has a major effect on the petrographic number. The petrographic analysis procedure, LS-609, August, 1983, provides only for the division of the Iron Formation into two categories, i.e.:

Good - Iron Formation (hard, medium hard)
Deleterious - Iron Formation (very soft)

A study of these Ironstone materials has shown that many gravel particles have an exterior that is hard, and an interior that is weathered and soft. Some particles show no external signs of the interior weathering. Others show pattern cracking in the hard, external shell. Certain particles are externally weathered and soft. Examples of these particles are shown in the photographs in Figure 4.

The method by which this weathering has occurred is not exactly understood. Several mechanisms have been postulated, including:

(1) The percolation of groundwater through particles dissolves out ferrous iron which oxidizes at the particle surface to form ferric iron. Ferric iron is very insoluble in most natural waters, and precipitates to form a rust-like mineral, limonite, a hydrated ferric oxide;

(2) Spheriodal weathering (oxidation) of the particle from the outside inwards, and

(3) Deposition of ferric oxide from an iron-rich groundwater to form an external crust to the particle.

PREVIOUS TEST RESULTS

Petrographic Numbers determined on material from the Deadman Pit since 1961 (see Table 2) indicate that it is of marginal quality for use as Granular 'A'. Granular Petrographic Numbers vary from 167 to 234 with an average of 201. M.T.C. Form 1010 requires Granular A to have a PN of less than 200. However, the high petrographic numbers and relatively low magnesium sulphate and Los Angeles Abrasion and Impact Losses of past testing programs did not make sense. The material was consequently accepted on the basis of these other results. It was recognized that a re-evaluation of the petrographic classification of the Ironstone Formation was necessary.

REDEFINITION OF PETROGRAPHIC CATEGORIES (Ironstone and Slate)

What is important to petrographic analysis is that the weathering phenomenon previously described is recognized, and that all particles of Ironstone Formation are broken open to enable them to be correctly classified. It must also be recognized that there can be a range in quality of these Ironstone materials in a given deposit. It is not realistic to classify Ironstone materials as only 'Good' or 'Deleterious'. The Ironstone materials have, therefore, been redefined as shown in Appendix 1.

Shale, slate, greywacke and argillite make up about 8 percent of the gravels in the Deadman Pit. Traditionally, slate has been combined with shale in the Deleterious category. On reflection, this procedure is not considered realistic, particularly in view of the hard and durable nature of some slates in Northern Ontario. Some difficulty can be experienced in differentiating between three materials i.e. slate, argillite and tuff-argillite. These materials have, therefore, been grouped together in the Poor and Deleterious categories as shown in Appendix 1. These new definitions, together with the existing Good and Fair categories for argillite, allow argillite to be classified into any of the four categories, Good through to Deleterious, depending on material quality.

In 1983, gravel samples from the Deadman Pit and other pits in the vicinity were tested in both Northwestern Region and the Soils and Aggregates Section using the new classification. Despite the highly varied and weathered nature of these deposits, the results from the two laboratories compared very favourably (see Table 3). However, PN results were still high relative to other test results.

FIELD PERFORMANCE STUDY

It was decided that it would be advantageous to study the performance of this material in the field. It is understood that the only major contract in which this material has been used is Contract 80-218, Highway 11/17 between Highway 61 and Oliver Road. On 5 October 1983, samples of Granular A were taken from the base course for examination and testing. Sample locations were as follows:

(1) Eastbound lane, 0.8 k east of intersection with Hwy. 51 and Arthur Street (83-B-40096);

(2) Westbound lane, 0.2 k west of intersection with Oliver Road (83-B-40097), and

(3) Westbound lane, 0.3 k west of intersection with Oliver Road (83-B-40098).

Samples were taken from below the outside wheel path in the driving lane. An examination of the pavement indicated that it is in good condition after a period of three years. In addition to these three samples from the road, a sample of a stockpile of Granular A from the Deadman Pit was taken in September, 1983. The four samples were submitted to a variety of tests. Results are presented in Table 5. Petrographic analyses were undertaken according to the new classification described above. With the exception of sample 83-B-40097, the results of the tests are very similar. Petrographic Numbers for

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the four samples range from 131 to 242, with an average of 192. All other tests suggest the material is suitable as Granular A, eg. percent passing 75 µm, Magnesium Sulphate Loss and Los Angeles Abrasion and Impact Loss.

The measurement of percent passing 75 µm on the samples from the road (i.e. 4.6, 6.3 and 5.7 percent) indicates that this material has not broken down detrimentally in the road over a period of three years. This was substantiated when the stockpile sample (83-B-40086) was subjected to gradation before and after Proctor compaction. Percent passing 75 µm increased from 5.1 to 7.0 remaining within the 8 percent requirement (see grading curves in Figure 5).

From this relatively limited field performance study, it is concluded that the material performs adequately. The petrographic classification of ironstone appears to be too harsh, and the introduction of petrographic granular correction factors to this rock type is considered appropriate.

GRANULAR CORRECTION FACTORS

Sample 83-B-40086 from a stockpile in Deadman Pit was subjected to routine testing. Results are presented in Table 4. As discussed, all test results except Petrographic Number indicate this material is suitable for use as Granular A. The introduction of granular correction factors for the Ironstone Formation is considered appropriate to reduce the granular PN to below 200.

Petrographic Number	Granular	Hot Mix & Concrete
No granular correction factors:	241.7	255.1
Correction factor for Ironstone (x2) in the Fair Category:	215.0	255.1
Correction factor for Ironstone (x2) in the Fair Category and (x3) in the Poor Category:	183.4	255.1

It is recommended that the latter case be introduced i.e. correction factors for Ironstone in the Fair category (x2) and in the Poor category (x3).

CONCLUSIONS AND RECOMMENDATIONS

1. The results of this limited field performance study and laboratory testing program (Table 4) indicate that the Granular A produced from the Deadman Pit appears suitable for use in highway construction.

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2. This material, however, generally fails the Petrographic Number requirement of 200 for Granular A. It is, therefore, recommended that:

   (a) Petrographic categories incorporating Ironstone and Slate be redefined as shown in Appendix 1. It is not considered realistic to classify Ironstone materials as only Good and Deleterious, as there is a range in quality in these materials, and

   (b) It is recommended that granular correction factors be applied to the Ironstone types in the Fair and Poor categories.

3. This study has been limited to the Deadman Pit. Others pits in the area more than likely contain similar gravels that would be suitable as Granular materials. A drilling and testing program is recommended which should include the Deadman Pit.

ACKNOWLEDGEMENTS

Bill Werbowetski's contribution to the redefinition of the ironstone and slate materials is gratefully acknowledged. Appreciation is also due to Chris Rogers for providing many useful ideas in connection with this project.

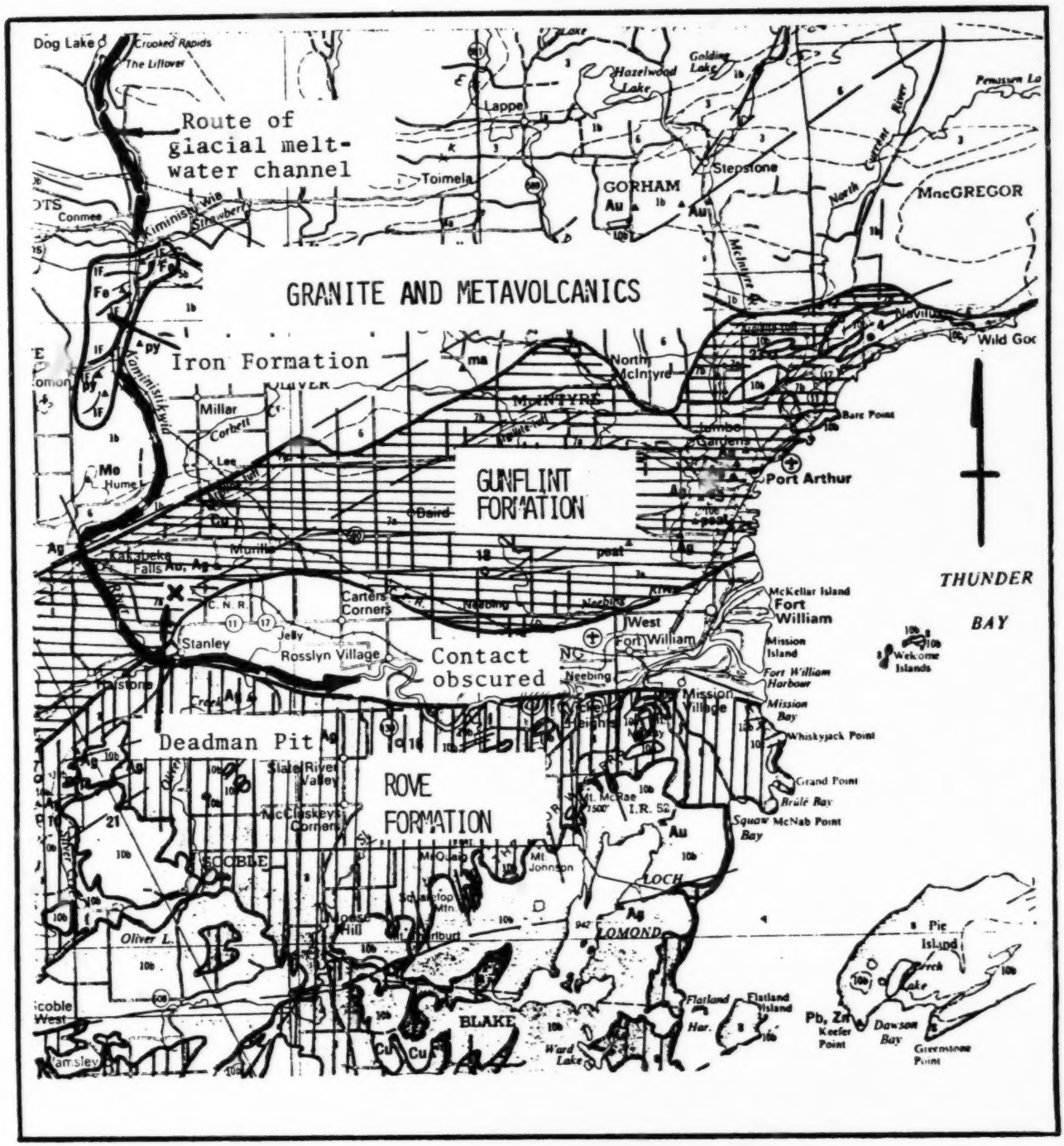


FIGURE 1

BEDROCK GEOLOGY IN VICINITY OF DEADMAN PIT

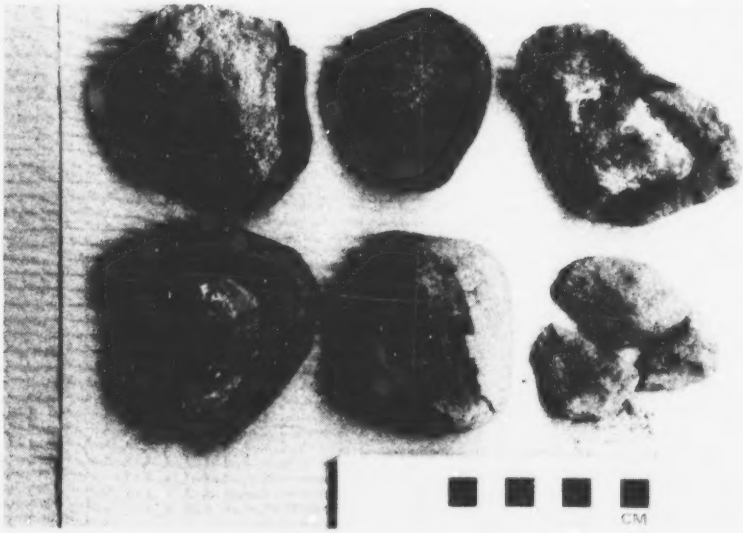
(based on Geological Compilation Series, Map 2065)

FIGURE 2

EXTENT OF KAMINISTIKWIA DELTA DEPOSITS

FIGURE 3
GLACIAL OUTWASH DEPOSITS IN THE DEADMAN PIT;
KAMINISTIKWIA DELTA DEPOSITS

Left: Deceptively hard exterior
Centre: Typical micro-cracking indicative of weathered interior
Right: Hard shell around soft interior



Variable nature of iron-rich gravels - hard to very soft

FIGURE 4
EXAMPLES OF WEATHERING IN IRON-RICH GRAVELS

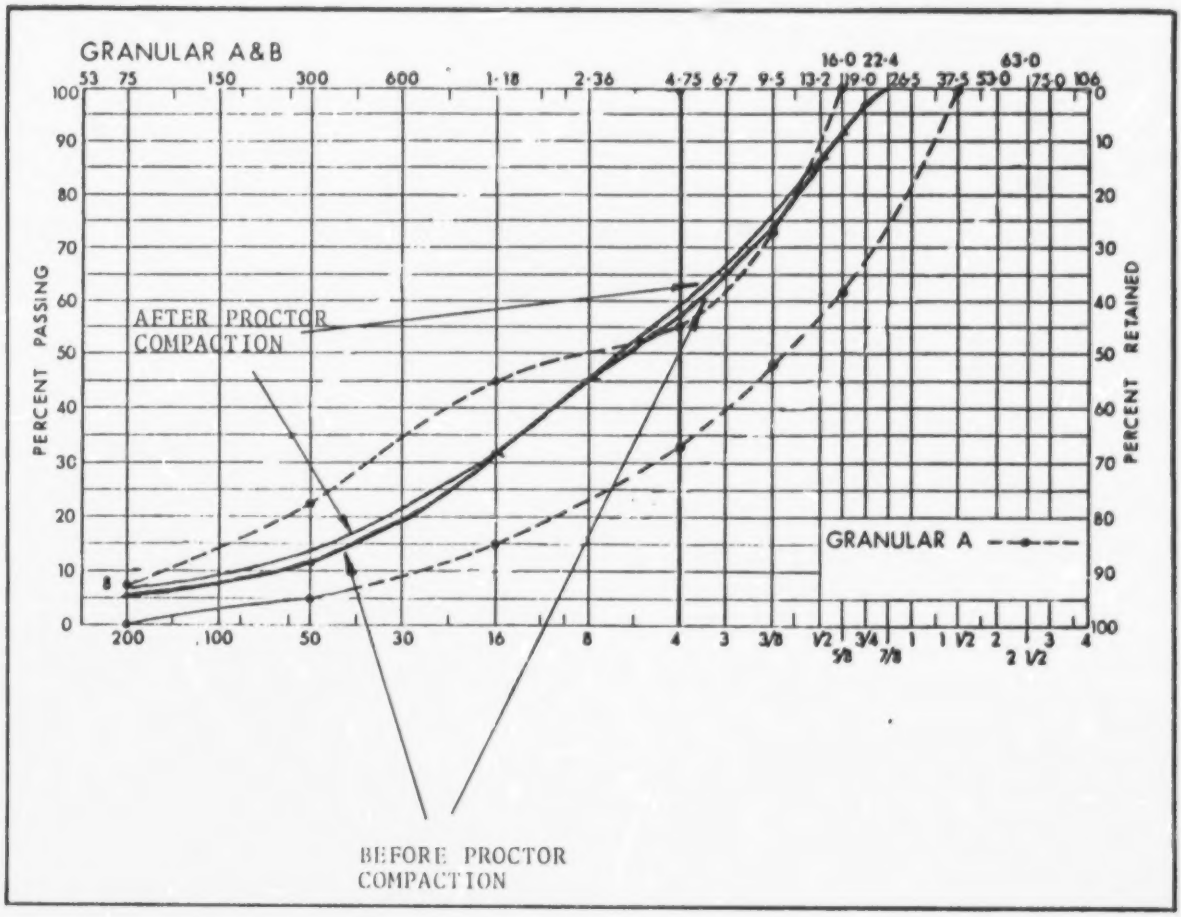

GRANULAR A&B
53 75 150 300 600 1·18 2·36 4·75 6·7 9·5 13·2 16·0 19·0 22·4 26·5 37·5 53·0 63·0 75·0 106
PERCENT PASSING
PERCENT RETAINED
AFTER PROCTOR COMPACTION
GRANULAR A
BEFORE PROCTOR COMPACTION
200 100 50 30 16 8 4 3 3/8 1/2 5/8 3/4 7/8 1 1 1/2 2 2 1/2 3 4

FIGURE 5

GRADING CURVE FOR GRANULAR A SAMPLE STOCKPILE FROM DEADMAN PIT (K17-016)

TABLE 1

Petrographic Summary
Deadman Pit, K17-016
West of Thunder Bay, Northwestern Region

	83-B-40086	83-B-40096	83-B-40097	83-B-40098
Sandstone-Arkose	0.3	9.2	1.6	0.9
Gneiss-Schist	2.5	-	8.0	3.6
Iron Formation	6.5	18.9	7.5	10.5
Greywacke-Argillite	11.3	0.3	7.2	2.2
Volcanic	1.4	1.8	0.9	0.3
Granite-Diorite-Gabbro	36.8	45.1	53.0	53.7
Trap	5.5	0.3	1.0	-
Quartzite	-	0.1	-	0.8
Sibley	-	0.1	1.5	-
PERCENT GOOD	64.4	75.8	80.8	72.1
Gneiss-Schist	0.2	-	0.7	0.9
Iron Formation	13.1	6.0	3.7	7.8
Greywacke-Argillite	1.3	3.3	0.1	0.3
Flint-Jasper	5.1	3.8	8.8	-
Granite-Diorite-Gabbro	-	0.3	0.1	-
Sandstone-Arkose	-	0.1	-	-
Chert	-	-	2.2	4.5
PERCENT FAIR	19.6	13.5	16.3	13.5
Schist	-	-	-	0.1
Sibley	-	0.1	-	-
Iron Formation	11.6	7.0	1.0	8.8
Sandstone-Arkose	-	0.6	0.1	-
Volcanic	-	0.2	-	-
Gneiss	-	0.1	-	-
PERCENT POOR	11.6	8.0	1.2	8.9
Ochre	0.4	-	-	-
Shale and Slate	1.5	1.9	0.4	1.9
Iron Formation	2.4	0.4	1.2	3.5
Volcanic	-	0.2	-	-
Sibley	-	0.1	-	-
PERCENT DELETERIOUS	4.4	2.6	1.6	5.5
TOTAL IRON FORMATION	33.6	32.3	12.7	30.6
WEIGHTED PETROGRAPHIC NUMBERS				
Granular	242	178	131	216
Hot Mix and Concrete	255	195	152	233

(Petrographic analysis was carried out using four (4) categories, but no granular correction factors.)

TABLE 2

PETROGRAPHIC NUMBER RESULTS FROM SAMPLES FROM DEADMAN PIT (K17-016), 1961 TO 1983

DATE TESTED	PETROGRAPHIC NUMBER H.L.	PETROGRAPHIC NUMBER GRANULAR	L.A. LOSS, %	$MgSO_4$ SOUNDNESS LOSS, %
June 1961	Old PN =	198.9	22.5	16.7
October 1961		166.9	-	11
November 1970	258.3	233.5	23	13
May 1973	219.5	195.1	21	12
May 1973	216.5	206.5	-	-
June 1980	-	192.8	-	-
1983	227	210	-	-

TABLE 3

PETROGRAPHIC NUMBER CORRELATION TESTING

PIT	AGGREGATE INVENTORY	SAMPLE # (83-B-)	PETROGRAPHIC NUMBER H.L. SA	H.L. NW	GRANULAR SA	GRANULAR NW
Deadman	K17-016	10009-9.5	241	259	219	231
		10016-9.5	231	197	205	180
		10016-6.7	279	279	264	262
		10016-comb.	248	227	226	210
Hacquoil -Stanley	K17-012	10011-9.5	204	208	185	181
		10014-9.5	190	-	174	-
		5001-9.5	217	234	193	206
Yarzabs/Corbett	K17-036	10015-9.5	170	-	156	-

NOTE: SA = Soils & Aggregates Section Results
NW = Northwestern Region Results

TABLE 4

Summary of Test Results on Granular A Samples
Taken from Highway 11/17 and
Deadman Pit (K17-016);
Thunder Bay, Northwestern Region

SAMPLE NO.	83-B-40086	83-B-40096	83-B-40097	83-B-40098
LOCATION	Deadman's Pit -stockpile	Hwy. 11/17 0.8 km east of intersection of Hwy. 61 and Arthur	Hwy. 11/17 0.2 km west of intersection with Oliver	Hwy. 11/17 0.3 km west of intersection with Oliver
	-	eastbound lane	westbound lane	westbound lane
CONTRACT	-	80-218	-	80-218
MATERIAL	Potential Gran. 'A'	Granular A	Granular A	Granular A
PETROGRAPHIC NO. GRAN	242	178	131	216
H.L.	255	195	152	233
IRON FM, 1st block	6.5	18.9	7.5	10.5
2nd block	13.1	6.0	3.7	7.8
3rd block	11.6	7.0	1.0	8.8
4th block	2.4	0.4	1.2	3.5
Total	33.6	32.3	13.4	30.6
SHALE/SLATE	1.5	1.9	0.4	1.9
PASS 75 µm	5.1	4.6	6.3	5.7
FM	4.53	5.13	4.18	4.36
PASS 75 µm } after compaction	7.0	-	-	-
FM } after compaction	4.47	-	-	-
$MgSO_4$ LOSS %	11	8	3	8
L.A. LOSS %	22	19.8	-	-
ABSORPTION %	2.81	2.19	1.27	2.14
BULK RELATIVE DENSITY	2.625	2.683	2.694	2.651
PERCENT CRUSHED	85	78	68	76
ATTRITION LOSS	14.5	-	-	-

APPENDIX 1

Type Descriptions for (1) Iron Formation
(2) Argillite-Tuff Argillite-Slate

IRON FORMATION

Good

Iron Formation (hard); High strength (cannot be scratched); unweathered.

Iron Formation (slightly weathered): Predominately high strength (can be scratched with difficulty); with less than 5 percent penetrating zones (eg. inner core) of low to medium strength, weathered material which can be scraped or gouged; possible partial to total thin surface weathering (rust stains).

Fair

Iron Formation (moderately weathered): Medium to high strength (scratched with difficulty) and brittle (thick outer crust that can be scraped and plucked with difficulty); with less than 25 percent penetrating zones (eg. inner core) of low to medium strength, weathered material which can be scraped or gouged.

Poor

Iron Formation (deeply weathered): Greater than 25 percent and less than 75 percent of particle (eg. inner core) consists of low strength weathered material which can be scraped or gouged with ease; with an outer crust containing zones of medium to low strength (scraped and plucked with moderate ease).

NOTE: Inner core may appear ochreous or pumice-like.

Deleterious

Iron Formation (decomposed): Low to very low strength; greater than 75 percent of particle consist of low strength, weathered material which can be scraped, peeled or gouged with ease.

NOTE: Slaty, platy or fissile pieces of iron formation to be included with Argillite-Tuff Argillite-Slate group.

ARGILLITE-TUFF ARGILLITE-SLATE

Poor

Argillite-Tuff Argillite-Slate (unweathered, fissile): Low to medium strength (can be scratched and scraped with ease); appears slaty and fissile (breaks along thin beds, and shatters when struck by hammer); generally characterized by length to thickness ratio less than 4 to 1

Deleterious

Argillite-Tuff Argillite-Slate (weathered, fissile): Low to very low strength (can be scraped and peeled with ease); appears slaty and very fissile (breaks readily along very thin beds or shatters easily when struck by hammer); weathering present as rust stains with penetration into the rock matrix; generally characterized by length to thickness ratio greater than 4 to 1.